Mesenteric shunting decreases visceral ischemia during thoracoabdominal aneurysm repair

Richard P. Cambria, MD, J. Kenneth Davison, MD, Joseph S. Giglia, MD, and **Jonathan P. Gertler, MD,** *Boston, Mass.*

Purpose: **A technique to decrease visceral ischemic time during thoracoabdominal aneurysm (TAA) repair is reported.**
Methods: **A 10 mm Dacron side-arm graft is attached to the aortic prosthesis and positioned immediately distal to the planned proximal thoracic aortic anastomosis. On completion of the anastomosis, a 16 to 22 Fr perfusion catheter is attached to the side-arm graft and inserted into the orifice of the celiac axis or superior mesenteric artery. The cross-clamp is then placed on the aortic graft distal to the mesenteric side-arm graft. Pulsatile arterial perfusion is thus established to the visceral circulation while intercostal anastomoses or reconstruction of celiac, superior mesenteric, and right renal arteries is performed. Visceral ischemic time and the rise in end-tidal P_{CO_2} after reconstruction of the visceral vessels in patients with mesenteric shunting was compared with a control group matched for aneurysm extent and treated immediately before use of the mesenteric shunt technique.**
Results: **Between July and Oct, 1996, the technique was applied in 15 patients undergoing type I, II, or III TAA repair with a clamp and sew technique. The mean decrease in systolic arterial pressure was 12.5 ± 8.5 mm Hg, with a concomitant rise in end-tidal P_{CO_2} (mean, 6.9 ± 5.8 mm Hg), after perfusion was established through the mesenteric shunt. Mean time to establishment of visceral perfusion through the shunt was 25.5 ± 4.4 minutes; the resultant decrement in visceral ischemic time averaged 31.3 minutes (i.e., until celiac, superior mesenteric, and right renal arteries were reconstructed). Compared with controls, patients with shunts had a significantly decreased (6.9 ± 5.8 versus 21.6 ± 8.4 mm Hg; p = 0.0003) rise in end-tidal CO_2 on completion of visceral vessel reconstruction.**
Conclusions: **In-line mesenteric shunting is a simple method to decrease visceral ischemia during TAA repair, and it is adaptable to clamp and sew or partial bypass and distal perfusion operative techniques. (J Vasc Surg 1998;27:745-9.)**

Major morbidity after thoracoabdominal aneurysm (TAA) repair varies inversely with the duration of aortic clamp time.[1] In particular, mesenteric ischemia has been implicated in the development of intraoperative coagulopathy, an important source of morbidity in TAA repair.[2-4] Whether this is related to liver ischemia, bacterial translocation, or other factors in ischemic gut is unknown, but prior work in our unit[4] and elsewhere has demonstrated major abnormalities in coagulation parameters after supraceliac aortic clamping.[5] In an effort to minimize visceral and renal ischemia, the surgeon may choose to omit intercostal vessel reconstruction, although most surgeons believe such reconstruction is important in avoiding spinal cord ischemia.[6-8] The use of partial bypass and distal aortic perfusion techniques has been advocated by some to limit renal and visceral ischemia.[9-11] However, even when combined with a sequential clamping technique, such bypass methods permit visceral perfusion only during performance of the proximal aortic anastomosis unless multiple selective perfusion cannulas are used.

Impressed with the profound metabolic and hemodynamic derangements that typically occur with reestablishment of visceral perfusion, we describe herein a method for rapid establishment of visceral perfusion immediately after perfor-

From the Divisions of Vascular Surgery and Anesthesia, Surgical Services, Massachusetts General Hospital, and Departments of Surgery and Anesthesia, Harvard Medical School.
Reprint requests: Richard P. Cambria, MD, Massachusetts General Hospital, 15 Parkman Street WAC 458, Boston, MA 02114.

0741-5214/98/$5.00 + 0 **24/4/88131**

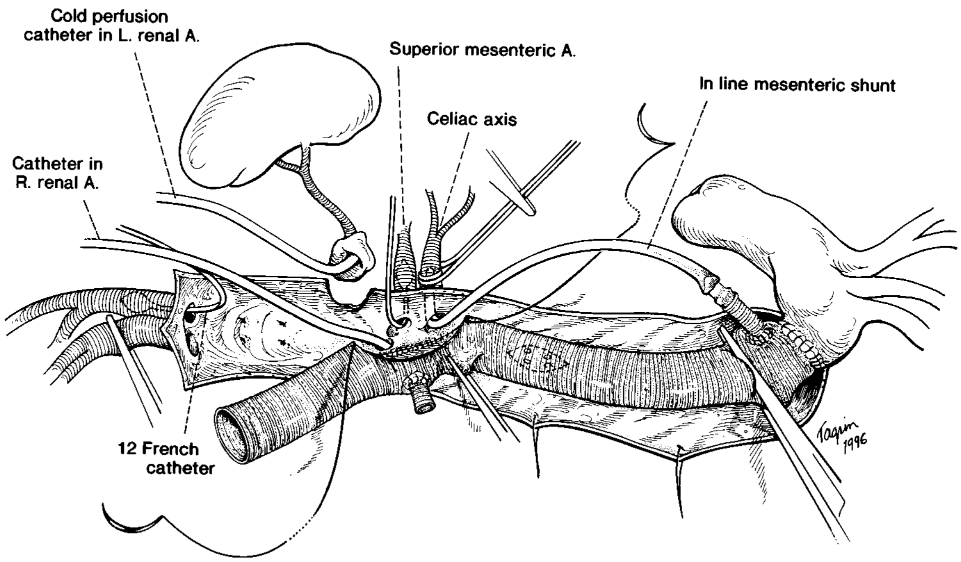

Fig. 1. Operative scheme for use of an in-line mesenteric shunt. The proximal thoracic aortic anastomosis has been completed, and the cross-clamp has been moved distal to the 10-mm Dacron side-arm graft, establishing flow through the shunt into the celiac axis. Notice that an intercostal inclusion anastomosis is completed, and the celiac, superior mesenteric, and right renal vessel reconstruction carried out after celiac perfusion is initiated. Because the spinal cord is protected with epidural cooling (not shown), there is no need to place the clamp distal to the intercostal reconstruction, where it can interfere with the visceral vessel reconstruction. The left renal artery is reconstructed with a preattached side-arm graft, and continuous cold perfusion of the renal arteries is performed with renal preservation solution until the renal arteries are reconstructed.

mance of the proximal thoracic aortic anastomosis in TAA repair.

OPERATIVE TECHNIQUE

Our general approach to TAA repair stresses operative simplicity and expediency; a clamp and sew technique has been routinely applied with specific, regional hypothermic adjuncts for renal and spinal cord protection. Overall results with this approach in the important parameters of operative mortality—renal failure and spinal cord ischemic complications—compare favorably with those of other contemporary reports.[7,12,13]

The thoracoabdominal incision is kept lateral on the abdominal wall and is transperitoneal with radial division of the diaphragm. Anterior dissection of the aneurysm is limited to identifying and encircling the celiac axis and the superior mesenteric artery. Left renal artery reconstruction is performed with a separate, preattached side-arm graft after reconstruction of the celiac, superior mesenteric, and right renal arteries with the inclusion button technique. Patent intercostal vessels in the T9-T12 region are reconstructed with the inclusion button technique in types I and II TAA or preserved in a beveled proximal aortic anastomosis in type III TAA.

The prosthesis is prepared by suturing a 10 mm Dacron graft to the aortic graft for subsequent mesenteric shunting (Fig. 1); a 6 mm polytetrafluoroethylene (PTFE) graft is used for the left renal artery reconstruction. Care is taken to place the mesenteric shunt graft so that it lies in proximity to the proximal aortic anastomosis; this prevents thrombus buildup in the aortic graft (heparin is not used). After application of the proximal clamp, the entire aneurysm is opened, and intercostal vessels in the T4 to T8 region are rapidly oversewn. Intercostals selected for reconstruction from T9 to T12 are balloon occluded, as is the right iliac vessel. A bolus of 250 ml of iced (4° C) Ringer's lactate with 25 g of mannitol and 1 g of methylprednisolone per 1 L is instilled into each renal artery orifice, and a continuous infusion of the same is begun in each renal artery.

After completion of the proximal aortic anastomosis, a 16 to 22 Fr arterial perfusion catheter (C.R. Bard Inc., Billerica, Mass.) is attached to the 10 mm Dacron side-arm by its phlanged plastic connected and secured with silk ties. The delivery end of the catheter is inserted into the celiac axis (or the superior mesenteric artery) after flushing, and its phlanged collar is secured with a silicone vessel-loop around the celiac axis. The proximal clamp is then moved down to aortic graft to just distal to the mesenteric side-arm (Fig. 1). Flow in the mesenteric shunt can be verified by palpation of pulsatile flow in the Dacron side-arm, Doppler interrogation of the celiac axis, and the observation of arterial backbleeding from the orifice of the superior mesenteric artery. A reduction in systemic arterial pressure and an increase in end-tidal CO_2 typically is seen after perfusion through the shunt is established.

The remainder of the reconstruction is completed as shown in Fig. 1. If a separate intercostal inclusion anastomosis has been performed, perfusion of these vessels is delayed until completion of the visceral inclusion button. Attempting to move the clamp distal to the intercostal inclusion button often precipitates thrombus buildup in the graft and interferes with performance of the visceral vessel inclusion button because it lies close to the critical intercostal segment anastomosis. With use of epidural cooling for regional spinal cord hypothermia,[12] the cord is protected during the clamp interval, and we feel no pressure to rapidly restore flow in reconstructed intercostal vessels.

Before completion of the visceral inclusion anastomosis, the shunt is clamped and removed from the celiac origin. After completion of the distal aortic anastomosis, the 10 mm Dacron side-arm graft is occluded and sutured.

PATIENTS AND RESULTS

From July through December 1996, in-line mesenteric shunting was used in 15 patients undergoing TAA resection (five type I, six type II, and four type III). Operative data relative to visceral ischemia were compared with 15 control patients exactly matched for aneurysm extent and complexity of repair (i.e., separate intercostal inclusion button) and treated in the 9 months before adoption of the mesenteric shunt technique. There were two emergent operations for rupture with hemodynamic stability, one urgent operation within 48 hours of admission for severe back pain, and 12 elective operations in the patients with shunts.

Flow in the mesenteric shunt (13 in celiac and 2 in superior mesenteric arteries) was established in a mean time of 25 ± 4.3 minutes (range, 18 to 34 minutes) after initial aortic clamping. Seven of 11 patients with type I or II TAA had intercostal vessels reconstructed with a separate inclusion button, and the mean cerebrospinal fluid temperature at clamping was 27° C. Mean time to completion of the celiac, superior mesenteric, and right renal arteries reconstruction was 56.2 ± 10.2 minutes (range, 36 to 74 minutes). Mesenteric shunting decreased the duration of visceral ischemia by an average 31.3 minutes (range, 12 to 43 minutes). With establishment of mesenteric shunting, the mean fall in systolic blood pressure was 12.5 ± 8.5 mm Hg, representing a 10% decrement from postclamp arterial pressures, which are typically kept in the systolic range of 100 to 120 mm Hg. The corresponding rise in end-tidal Pco_2 was 6.9 ± 5.8 mm Hg with establishment of flow in the shunt. Although visceral clamp time in shunted patients did not differ from controls (56.2 ± 10.2 versus 53.9 ± 13.5 minutes; $p = 0.6$), there was a significant reduction in end-tidal CO_2 (6.9 ± 5.8 versus 21.6 ± 8.4 mm Hg; $p = 0.0003$) in shunted patients after completion of the visceral artery reconstruction. Transfusion requirements in patients with shunts averaged 1187 ml (range, 240 to 2800 ml) of autotransfused blood, 5.5 units of banked packed red blood cells, 5.3 units of fresh-frozen plasma, and 13.5 units of platelets; these figures are similar to those for patients without shunts.

No patient had evidence of coagulopathic bleeding, and with the exception of a preoperatively dialysis-dependent patient with a prolonged hospital course, postoperative hospital stay averaged 15.1 days. No lower extremity neurologic deficits occurred. For patients with shunts, other significant complications included unstable angina (1 patient), pulmonary embolism (2), reoperation for bleeding–splenectomy (1), and pulmonary insufficiency (2). There were no perioperative deaths in either group. Complications in patients without shunts included respiratory insufficiency (1) and reexploration for bleeding (2); one patient undergoing reexploration had delayed paraparesis coincident with bleeding and hypotension.

DISCUSSION

Extensive perioperative hemorrhage has been a significant source of morbidity and mortality after TAA resection. In addition to dilutional coagulopathy associated with significant surgical blood loss, visceral ischemia has been implicated in the genesis of coagulopathic bleeding.[1-5] Profound metabolic and hemodynamic derangements are often observed after reestablishment of visceral perfusion during TAA repair. Our prior studies[4] and those of Illig et al.[5] documented the qualitative and quantitative derangements in clotting factors and fibrinolytic activity that occur 30 minutes after placement of a supraceliac clamp. A subclinical state of consumption coagulopathy and increased fibrinolysis is observed, and these changes are significantly different from those observed after infrarenal aortic clamping.[4] We previously documented that the technique reported here accelerated the recovery of a battery of coagulation factors that are typically depressed with supraceliac clamping.[14] These findings together with our prior observations about the negative impact of prolonged (>1 hour) visceral ischemia on spinal cord complications[12] convinced us that minimizing visceral ischemic time is an important component of the intraoperative management of TAA.

Among the technical maneuvers to minimize visceral and renal ischemia during TAA repair, routine distal aortic perfusion combined with a sequential clamping technique has gained favor among some surgeons.[9-11] Our criticism of this method is that it generally allows renal, visceral, and critical intercostal perfusion only during performance of the proximal anastomosis, but most "clamp time" is expended in the performance of intercostal reconstruction and performance of the visceral and right renal inclusion anastomosis. We reserve the atriofemoral bypass and sequential clamping technique for the uncommon circumstance in which undue technical complexity in the proximal anastomosis is anticipated. Some surgeons have advocated multiple renal and visceral perfusion cannulas off the atriofemoral bypass circuit to circumvent this limitation; results, at least with respect to renal failure, have not been optimal.[15] Savader et al.[16] demonstrated with angiographic studies that the greater radicular artery originated between T9 and T12 in 75% of TAA patients when this vessel could be visualized. The critical intercostal segment and the visceral inclusion anastomosis lie in proximity and cannot be separated with a sequential clamping technique.

In-line mesenteric shunting as reported here was originally tried in a dog model by Cohen et al.[17] They demonstrated abrogation of coagulation abnormalities in simulated TAA repair by continuous arterial perfusion of the superior mesenteric artery. This study was related to prior investigations indicating that altered intestinal permeability with clamping, rather than hepatic ischemia, was responsible for coagulopathic bleeding.[3] Illig et al.[5] suggested that hepatic ischemia with resultant primary fibrinolysis was the more important factor.

Debate continues about whether shunting into the celiac or superior mesenteric artery would be more appropriate. Our initial choice of the celiac axis was based on anatomic simplicity, although we have used the superior mesenteric artery in circumstances of celiac stenosis or occlusion. In human arterial collateral pathways, either vessel will probably suffice, and we have typically observed pulsatile arterial backbleeding through the superior mesenteric artery orifice with celiac perfusion. The technique could be adapted to perfuse the celiac and superior mesenteric arteries or the renal artery orifices in patients at particular risk for renal failure. The notation of relative hypotension and an increase in end-tidal CO_2 with establishment of the mesenteric shunt indicates a degree of visceral perfusion. However, similar changes after completion of the visceral reconstruction indicate that visceral perfusion is not normalized with the shunt, and this probably reflects limitations of catheter diameter and length. The technique reported here is simple, does not require systemic heparin, and can be used with clamp and sew or distal perfusion with sequential clamping operative techniques.

REFERENCES

1. Svensson LG, Crawford ES, Hess KR, Coselli JS, Safi HJ. Experience with 1509 patients undergoing thoracoabdominal aortic operations. J Vasc Surg 1993;17:357-68.
2. Cohen JR, Angus L, Asher A, Chang JB, Wise L. Disseminated intravascular coagulation as a result of supraceliac clamping: implications for thoracoabdominal aneurysm repair. Ann Vasc Surg 1987;1:552-7.
3. Cohen JR, Sardari F, Paul J, Parikh S, Sarfati I, Danna D, et al. Increased intestinal permeability: implications for thoracoabdominal aneurysm repair. Ann Vasc Surg 1991;6:433-37.
4. Gertler JP, Cambria RP, Laposata M, Abbott WM. Coagulation changes during thoracoabdominal aneurysm repair. J Vasc Surg 1996;24:936-45.
5. Illig KA, Green RM, Ouriel K, Riggs PN, Bartos S, Whorf R, et al. Primary fibrinolysis during supraceliac aortic clamping. J Vasc Surg 1997;25:244-54.
6. Svensson LG, Hess KR, Coselli JS, Safi HJ. Influence of segmental arteries extent and atriofemoral bypass on postoperative paraplegia after thoracoabdominal aortic operations. J Vasc Surg 1994;20:255-62.
7. Cambria RP, Davison JK, Zannetti S, L'italien G, Atamian S. Thoracoabdominal aneurysm repair: perspectives over a decade with the clamp and sew technique. Ann Surg 1997;226:1-10.
8. Safi HJ, Miller CC, Carr C, Iliopoulos DC, Dorsay DA, Baldwin JC. Importance of intercostal artery reattachment during thoracoabdominal aortic aneurysm repair. J Vasc Surg 1998;27:58-68.
9. Safi H, Hess KR, Randel M, et al. Cerebrospinal fluid drainage and distal aortic perfusion: reducing neurologic complications in repair of thoracoabdominal aortic aneurysms, type I and type II. J Vasc Surg 1996;23:223-8.

10. Schepens M, Defauw J, Hamerliiknck R, Vermeulen F. Use of left heart bypass in the surgical repair of thoracoabdominal aortic aneurysms. Ann Vasc Surg 1995;9:327-38.
11. Frank S, Parker S, Rock P, et al. Moderate hypothermia with partial bypass and segmental sequential repair for thoracoabdominal aortic aneurysm. J Vasc Surg 1994;19:687-97.
12. Cambria RP, Davison JK, Zannetti S, et al. Clinical experience with epidural cooling for spinal cord protection during thoracic and thoracoabdominal aneurysm repair. J Vasc Surg 1997;25:234-43.
13. Kashap V, Cambria RP, Davison JK, L'Italien G. Renal failure after thoracoabdominal aortic surgery. J Vasc Surg 1997;26:949-57.
14. Gertler JP, Cambria RP, Makary MA, Davison JK, Brewster DC, Johnson S, et al. Correction of coagulation defect in thoracoabdominal aneurysm repair by mesenteric shunting. Presented at the 24th meeting of the New England Society for Vascular Surgery; Bolton Landing, NY, September 19, 1997.
15. Safi HJ, Harlen SA, Muller CC. Predictive factors for acute renal failure in thoracic and thoracoabdominal aortic aneurysm surgery. J Vasc Surg 1996;24:338-45.
16. Savader SJ, Williams GM, Trerotola SO, et al. Preoperative spinal artery localization and its relationship to postoperative neurologic complications. Radiology 1993;189:165-71.
17. Cohen JR, Schroder W, Leal J, Wise L. Mesenteric shunting during thoracoabdominal aortic clamping to prevent disseminated intravascular coagulation in dogs. Ann Vasc Surg 1988;2:261-7.

Submitted Aug. 15, 1997; accepted Dec. 11, 1997.